DATA CONSISTENCY FOR MIRRORING UPDATABLE SOURCE DATA STORAGE

FIELD OF THE INVENTION

This invention relates to mirroring of data storage in an information handling system, and, more particularly, to mirroring in a fashion that is similar to asynchronous mirroring.

BACKGROUND OF THE INVENTION

Asynchronous mirroring is a popular way of duplicating data storage, for example, for the purpose of disaster recovery. Synchronous mirroring requires that data be stored by both a source and a target data storage before the storage transaction is considered complete. Asynchronous mirroring requires that the data first is stored by the source data storage, and that it will ultimately be stored at the target data storage, and that safeguards are in place to insure that the data can be tracked. Asynchronous mirroring allows the host or immediate source of the data to consider the storage transaction complete when the data is first stored by the source data storage. The asynchronous mirroring system then ultimately stores the data at the target data storage. As the result, implementation of asynchronous mirroring is much more complex than synchronous mirroring.

It is advantageous for disaster recovery to have the duplicated data storage at a site or location remote from that of the source data storage. The time required for distant verified

communication of the data may be considerable, especially if large numbers of blocks or files (called "grains") are to be mirrored. As the result, asynchronous mirroring is preferable from a time standpoint as compared to synchronous mirroring which requires actual storage by both a source and a target data storage before each storage transaction is considered complete.

SUMMARY OF THE INVENTION

The present invention comprises an information handling system, a computer program product, a method, and a mirroring controller for mirroring in a fashion that is similar to asynchronous mirroring, but less complex in function, such as employing synchronous mirroring.

In one embodiment, an information handling system for mirroring data comprises:

source data storage for storing and updating data;

first intermediate data storage for storing data, the first intermediate data storage associated with the source data storage;

target data storage for storing data;

second intermediate data storage for storing data, the second intermediate data storage associated with the target data storage; and

mirroring control conducting first cyclic incremental flashcopy of the source data storage to the first intermediate data storage, the beginning of each first cyclic incremental flashcopy comprising a consistency point, the first cyclic incremental flashcopy synchronously mirrored to the second intermediate data storage; and conducting a second cyclic incremental flashcopy of the second intermediate data storage to the target data storage, the second cyclic incremental

flashcopy beginning in response to completion of the first cyclic incremental flashcopy; the beginning of the second cyclic incremental flashcopy comprising commit of the consistency point.

"Incremental flashcopy" is an improvement to backup sidefiles. With backup sidefiles, when a data file is to be updated before it can be physically copied to a target, entries are made to a "sidefile", for example in cache memory, to capture modifications or to preserve a previous data image, and the new data may then update the original data in the source file. Once backup copies have been made of the data, the sidefile entries are erased. In the present invention, incremental flashcopy is a repeating occurrence, additionally tracking the grains that have been modified in the source data storage after the initiation of the present flashcopy.

In a further embodiment, the information handling system comprises source data storage for storing and updating data; first intermediate data storage for storing data; and mirroring control conducting first cyclic incremental flashcopy of the source data storage, the beginning of each first cyclic incremental flashcopy comprising a consistency point. The first cyclic incremental flashcopy is synchronously mirrored to the first intermediate data storage and to a second intermediate data storage for storing data; and, in a loop, the mirroring control initiates another first cyclic incremental flashcopy of the source data storage in response to a commit of the consistency point; wherein the commit of the consistency point comprises the beginning of a second cyclic incremental flashcopy of the second intermediate data storage to a target data storage, the second cyclic incremental flashcopy beginning in response to completion of the first cyclic incremental flashcopy.

In a still further embodiment, the mirroring control additionally responds to an update write for the source data storage, determining whether data of the source data storage to be overwritten by the update write is present at the first intermediate data storage and the synchronously mirrored second intermediate data storage. If so, the mirroring control allows the update write to be written to the source data storage, and indicates the update write in a future flashcopy map.

In another embodiment, the future flashcopy map of the mirroring control is employed for conducting the next first cyclic incremental flashcopy of the source data storage.

In still another embodiment, the first cyclic incremental flashcopy conducted by the mirroring control employs a first flashcopy map indicating required, and not completed, mirroring of grains of the source data storage, and, in response to completion of mirroring of the grains indicated by the first flashcopy map and the commit of the consistency point, the mirroring control updates the first flashcopy map with the future flashcopy map.

In a further embodiment, the first cyclic incremental flashcopy conducted by the mirroring control employs a first flashcopy map indicating required, and not completed, mirroring of grains of the source data storage, and the mirroring control merges the first flashcopy map with the future flashcopy map to generate a new first flashcopy map, and resets the future flashcopy map; the beginning of the new first cyclic incremental flashcopy comprising a consistency point.

In another embodiment, wherein the target data storage and the second intermediate data storage are remotely located with respect to a locally located source data storage and first intermediate data storage; the information handling system additionally comprises at least one

interface at the target data storage and the second intermediate data storage for interfacing the mirroring control and the source data storage with at least one communication system for communicating between the remote and local locations.

For a fuller understanding of the present invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an embodiment of an information handling system in accordance with the present invention;

FIGS. **2A**, **2B** and **2C** are schematic representations of the operation of the information handling system of FIG. **1**;

FIGS. **3**, **4**, **5** and **6** are schematic representations of data and of bit maps employed in accordance with an embodiment of the present invention;

FIG. **7** is a flow chart depicting mirroring in accordance with an embodiment of the present invention; and

FIG. **8** is a flow chart depicting reading data in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

This invention is described in preferred embodiments in the following description with reference to the Figures, in which like numbers represent the same or similar elements. While this invention is described in terms of the best mode for achieving this invention's objectives, it

will be appreciated by those skilled in the art that variations may be accomplished in view of these teachings without deviating from the spirit or scope of the invention.

FIG. **1** illustrates an information handling system **20** for, inter alia, mirroring data, in accordance with an embodiment of the present invention. A first data storage system **24** is in communication with a host system **22**, and comprises the source data storage, and is in further communication with a second data storage system **44**, which comprises the target data storage, and may be located remotely from the first data storage system **24**, for example, for disaster recovery. The host system **22** may comprise a single data processing system, or a network of processing systems, etc., and provide the data for storage and mirroring, and request storage and/or retrieval of the data, e.g., at an interface **25** of the first data storage system **24**. Each of the first data storage system **24** and the second data storage system **44** may also be considered an information handling system.

An example of a first data storage system **24** and of the second data storage system **44** comprises an IBM Enterprise Storage Server (ESS), sold by the IBM Corporation. The first data storage system **24** and the second data storage system **44** may be similar or identical information handling systems, or may comprise differing systems having a common communication protocol, and are in communication with each other via interfaces **33** and **43**, respectively, and a communication link **35**. Examples of communication protocol comprise ESCON, SCSI, Fibre Channel, etc., as is known to those of skill in the art. For the purpose of disaster recovery, the first data storage system **24** and the second data storage system **44** are best located remotely from one another, for example, in different cities, or even different continents. The communication

link **35** between the first data storage system **24** and the second data storage system **44** may therefore be commercially available long distance high speed data links.

The first data storage system **24** and the second data storage system **44** each comprises a controller **28** and **48**, respectively, having a cache memory **26** and **46**, and a nonvolatile storage **27** and **47**. The controller may be implemented as one or more microprocessors comprising a programmable computer processor usable with a computer program product having computer readable code embodied therein. Mirroring control may be implemented as a computer program product for the controller **28** and/or controller **48**. The computer program product may be supplied from a network at interface **24**, or by means of a machine readable media, such as optical disk or magnetic disk media or tape.

The cache memory **26** and **46** buffers data as it is received from the host system **22** or transferred within or between the first data storage system **24** and the second data storage system **44**. The nonvolatile storage **27** and **47** may also store data, and stores data that is needed as potential backup in case of a power outage of the first data storage system **24** or of the second data storage system **44**, such as bit maps, as will be discussed.

The controller **28** and controller **48** each operates a data storage **29** and **49** of data storage devices **30** and **50**, respectively. The data storage may be arranged into various logical data storage units. For example, the data storage devices may be arranged as an array with logical data storage partially occupying all or some of the data storage devices. In the example of the IBM ESS, the data storage devices **30** and **50** comprise magnetic disk drives or arrays of

magnetic disk drives. Similarly, the data storage devices **30** and **50** may comprise optical drives or arrays, or devices that have direct or random access characteristics.

FIGS. **2A**, **2B** and **2C** illustrate mirroring in accordance with an embodiment of the present invention. Source data storage **61** and first intermediate data storage **62** comprise logical data storage of the first data storage system **24**, such that the first intermediate data storage **62** is associated with the source data storage **61**. Target data storage **64** and second intermediate data storage **63** comprise logical data storage of the second data storage system **44**, such that the second intermediate data storage **63** is associated with the target data storage **64**.

An initial state of the mirroring process may be that no mirroring has occurred and that the entirety of source data is to be mirrored. In that initial process, the data to be mirrored is stored, or is in the process of being stored, to source data storage **61**, and no mirrored data is stored to target data storage **64**. Initially, the mirroring control of controller **28** of the first data storage system **24** conducts a first cyclic incremental flashcopy **70** of the source data storage, the beginning of each first cyclic incremental flashcopy comprising a consistency point, comprising the data to be mirrored as depicted at a time "**t1**", and synchronously mirrors **71** the first cyclic incremental flashcopy to the first intermediate data storage **62** and to the second intermediate data storage **63**.

"Incremental flashcopy" is an improvement to backup sidefiles. With backup sidefiles, when a data file is to be updated before it can be physically copied to a target, entries are made to a "sidefile", for example in cache memory **26**, **46** in FIG. **1**, to capture modifications or to preserve a previous data image, and the new data may then update the original data in the source file. Once backup copies have been made of the data, the sidefile entries are erased.

In the present invention, referring to FIGS. **2A**, **2B** and **2C**, incremental flashcopy is a repeating occurrence, additionally tracking the grains that have been modified in the source data storage after the initiation of the present flashcopy. Normal flashcopy tracks all the data that was at the source data storage when the flashcopy was started, and may be at the source data storage or at a backup. As a data grain is copied to a target, the flashcopy so indicates in a sidefile, and once the backup copies have been made of the data, the sidefile entries are erased.

Incremental flashcopy additionally tracks grains that have been modified in the source data storage after the initiation of the present flashcopy. The tracked modified data grains then comprises a future, or incremental, flashcopy, as will be discussed.

In the present invention, once a data grain has been copied to the first intermediate data storage **62** and synchronously copied to the second intermediate data storage **63** of the second data storage system **44**, and a command complete has been received by the controller **28** of FIG. **1** to complete the synchronous copy of that grain, the grain may be modified or updated in the source data storage **61** of FIG. **2A**. The original data of the grain is then available, if needed for backup, at the first intermediate data storage **62** and the second intermediate data storage **63**.

Additionally referring to FIG. **2B**, in response to completion of the first cyclic incremental flashcopy **70**, such that the entirety of the data at the consistency point "**t1**" has been copied to the first intermediate data storage **62** and synchronously copied to the second intermediate data storage **63**, the mirroring control of controller **48** of FIG. **1** conducts a second cyclic incremental flashcopy **73** of the second intermediate data storage **63** to the target data storage **64** of FIG. **2B**, the beginning of the second cyclic incremental flashcopy comprising commit of the consistency point of the original mirrored data as depicted at time "**t1**". The

commit of the consistency point is made at time "**t2**", and is communicated **75** over a communication link to the mirroring control of controller **28** of FIG. **1**. The commit means that the entirety of the data at the consistency point "**t1**" has been copied to the second data storage system **44** of FIG. **2A** and is available for data recovery if needed. Specifically, the data has been copied to the second intermediate data storage **63**, and is being transferred to the target data storage **64**.

At this point, referring to FIG. **2C**, cyclic or continuous mirroring of the source data storage **61** is conducted. Modification or updates to grains of the source data storage **61** have been tracked by the first cyclic incremental flashcopy, and, at a new desired time, for example, in response to receipt, by mirroring control of controller **28**, of the commit from the mirroring control of controller **48** of FIG. **1**, the mirroring control of controller **28** conducts a new first cyclic incremental flashcopy **80** of the source data storage **61** of FIG. **2C**, and again, the beginning of each first cyclic incremental flashcopy comprises a consistency point, comprising the data of grains tracked by the previous first cyclic incremental flashcopy that have been modified or updated and are to be mirrored, as depicted at a new time "**t1**", and copies the present first cyclic incremental flashcopy to the first intermediate data storage **62**, synchronously mirroring **81** the data of the grains to the second intermediate data storage **63**.

Also again, once a data grain has been copied to the first intermediate data storage **62** and synchronously mirrored to the second intermediate data storage **63** of the second data storage system **44**, and a command complete has been received by the controller **28** of FIG. **1** to complete the synchronous copy, the grain may be modified or updated in the source data storage **61** of FIG.

2C. The new original data of the grain is then available, if needed for backup, at either the first intermediate data storage **62** or the second intermediate data storage **63**.

In response to completion of the first cyclic incremental flashcopy **80**, such that the entirety of the data grains at the new consistency point "**t1**" has been copied to the first intermediate data storage **62** and to the second intermediate data storage **63**, the mirroring control of controller **48** of FIG. **1** conducts a second cyclic incremental flashcopy **83** of the second intermediate data storage **63** to the target data storage **64** of FIG. **2C**, the beginning of the second cyclic incremental flashcopy comprising commit of the consistency point of the original mirrored data as depicted at new time "**t1**". The commit of the consistency point is made at new time "**t2**", and is communicated **85** over a communication link to the mirroring control of controller **28** of FIG. **1**. The commit means that the entirety of the data of grains tracked by the previous first cyclic incremental flashcopy that have been modified or updated at the consistency point "**t1**" has been copied to the second data storage system **44** of FIG. **2C** and is available for data recovery if needed. Specifically, the data has been copied to the second intermediate data storage **63**, and is being transferred to the target data storage **64**.

The cyclic operation of the present invention then continues, without the necessity of completing the second cyclic incremental flashcopy **83**. For example, each time that a commit is made and data that has been modified or updated is being transferred to the target data storage **64**, the tracking of the data grains that have been modified or updated from the immediately preceding cycle is updated with the identification of grains that have been modified or updated in the latest cycle.

In one embodiment, the first cyclic incremental flashcopy and synchronous mirroring of the data of the grains to be copied is conducted in an ordered fashion, for example, based on a sequence of access of the source data storage. In another embodiment, an update write for data of a grain whose present data has not yet been copied, causes the mirroring control **28** to immediately copy the present data of the grain to the first intermediate data storage **62** and synchronously mirror the data to the second intermediate data storage **63**. Thus, the mirroring control **28** responds to an update write for the source data storage **61**, determining whether data of the source data storage to be overwritten by the update write is present at the first intermediate data storage **61** and the synchronously mirrored second intermediate data storage. If so, the mirroring control **28** allows the update write to be written to the source data storage, and indicates the update write. If not, else, the mirroring control **28** immediately copies the present data of the grain to be overwritten to the first intermediate data storage **62**, synchronously mirroring the data to the second intermediate data storage **63**. Then, upon completion of the storage of the data at first intermediate data storage **62** and second intermediate data storage **63**, the mirroring control **28** allows the update write to be written to the source data storage.

FIGS. **3**, **4**, **5** and **6** illustrate an embodiment for tracking the grains of data for an incremental flashcopy **80** or an incremental flashcopy **83**, employing a bit map **90** and a future bit map **91**. The bit maps are stored, for example, by the nonvolatile storage **27** and **47** of the data storage systems **24** and **44**, respectively, of FIG. **1**. In each of the FIGS. **3**, **4**, **5** and **6**, a source data storage **61** and a first intermediate data storage **62** are illustrated, for example, as during a first cyclic incremental flashcopy **80**. The data of the grains of the second intermediate data

storage **63** are identical to those of the first intermediate data storage **62** because the data is synchronously copied to both.

The same bit maps are employed in the second cyclic incremental flashcopy **83** to copy data grains from the second intermediate data storage **63** to the target data storage **64**.

The bit maps **90** and **91** are illustrated as logically ordered in the same order as data grains are stored in the data storages **61** and **62**. Additionally, the data storages are illustrated as having the data stored in an ordered fashion. In the example, bit position **94** of bit map **90** represents grain **95** of data storage **62**, and bit position **96** of future bit map **91** represents grain **97** of data storage **61**. In fact, the data grains may be distributed throughout an array of the data storage devices **30** and/or **50** of FIG. **1**, and the bit maps may be ordered in any fashion which provides an identification or representation of the data grains.

FIG. **3** illustrates an incremental flashcopy, for example, during an initial state of the copying process when the data to be copied is stored, or is in the process of being stored to source data storage **61**, and no data is stored to the flashcopy target data storage. Data storage **61** is illustrated as having all of the data to be copied, and data storage **62** is illustrated as beginning to be filled with copies of the data grains of data storage **61**, while the remainder of data storage **62** is empty. In the example, data has been copied to data storage **62** to the point that data grain "**0103**" has just been copied. The bit map **90** reflects the state of the copying, and has a "**0**" at each bit position representing a grain that has not been copied, and has a "**1**" at each bit position representing a grain that has been copied. In the example, for the first incremental flashcopy **70**, the bit representing a grain is "set" to "**1**" when the data of the grain is copied to the first

intermediate data storage **62** and synchronously mirrored **71** to the second intermediate data storage **63** during the first cyclic incremental flashcopy **70** of FIG. **2A**. Similarly, for the second incremental flashcopy **73**, the bit representing a grain is "set" to "**1**" when the data of the grain is copied from the second intermediate data storage **63** to the target data storage **64** during the second incremental flashcopy **73** of FIG. **2B**.

Thus, if there is a desire to access data grain **97**, bit position **94** of bit map **90** indicates that the data is at grain **95** of data storage **62**, and, if, instead, there is a desire to access data grain **98**, bit position **99** of bit map **90** indicates that the data has not been copied and is at grain **98** of data storage **61**.

FIG. **4** illustrates the incremental flashcopy of FIG. **3**, advanced to the point that data grain "**0103**" has been copied to data storage **62**, and a modification or update has been made to the data grain, such that the data grain **100** now appears as data grain "**0103A**". Therefore, the bit **101** of the future bit map **91** representing grain **100** is set to "**1**". If there is a desire to access the original data of grain **100** before modification or update, bit position **102** of bit map **90** indicates that the data is at grain **103** of data storage **62**, and, if, instead, there is a desire to access the updated data grain **100** after the original data has been copied and after the data has been modified or updated, bit position **101** of future bit map **91** and bit position **102** of bit map **90** indicate that the updated data is at grain **100** of data storage **61**. The future bit map **91** only has a value after the original data has been copied and the data is modified later.

FIG. **5** illustrates an incremental flashcopy, for example, during a cyclic or continuous mirroring of the source data storage **61** with respect to target data storage **64**. Data storage **61** is

illustrated as having all of the original data excluding the data that has been modified or updated. The data at grains **110**, **111**, **112** and **113** has been modified or updated and is to be mirrored. First intermediate data storage **62** (and second intermediate data storage **63**) is illustrated as having at least the original data that is to be replaced by the modified or updated data of data storage **61**, while the remainder of data storage **62** may have the remaining original data before the most recent update. Thus, at the beginning of a cyclic mirroring, the data storage **62**, **63** comprises the previous state of the mirrored data, at the consistency point to which a commit has been made. If any of the data storage **61**, **62** is temporarily employed for other activities or destroyed, the original data will be found at target data storage **64** of FIG. **2**.

In FIG. **4** and in FIG. **5**, the bit map **90** must be updated to indicate the data to be copied from the source data storage **61** to the data storage **62**. This comprises employing the future flashcopy map **91** of the mirroring control for conducting the next first cyclic incremental flashcopy of the source data storage.

In one embodiment, the first cyclic incremental flashcopy conducted by the mirroring control employs a first flashcopy map **90** indicating required, and not completed, mirroring of grains of the source data storage, as discussed above, and, in response to completion of mirroring of the grains indicated by the first flashcopy map and the commit of the consistency point, the mirroring control updates the first flashcopy map **90** with the future flashcopy map **91**.

In one example, at completion of the mirroring of the grains, the first flashcopy map is all "**1**", and the bits of the future flashcopy map **91** are inverted, and the future flashcopy map with the inverted bits becomes the first flashcopy map **90**. Thus, the new first flashcopy bit map **90** indicates (e.g. as "**0**") only the grains that have been modified or updated and are to be mirrored.

The bit positions of the grains that have not been modified or updated are inverted to "1", as is illustrated in FIG. **5**. The data is thereby indicated as being the same at both the source data storage **61** and the intermediate data storage **62**, **63** for the "1" bits of the new first flashcopy bit map **90**.

In another example, which does not require that the previous mirroring of the grains be completed, the bits of the future flashcopy map **91** are "exclusive ORed" with the bits of the first flashcopy map **90** to form a new first flashcopy map **90**. Alternatively, the first flashcopy map may be ANDed to NOT of the future flashcopy map. Any data grains that have been mirrored will have a "1" in bit map **90**, any data grains that have not yet been mirrored will have a "0" in bit map **90**. Any data grains that have been modified or updated will have a "1" in future flashcopy bit map, and those data grains will have a "1" in the first flashcopy map since they will have to have been successfully copied before the modification or update of the data grain in data storage **61**. As the result of the "exclusive OR", data grains that have been modified or updated will have a "0" in the new first flashcopy map and will be copied; any data grains that had not been successfully mirrored will also have a "0" in the new first flashcopy map and will be copied; and any data grains that had been successfully mirrored and have not been updated or modified will have a "1" in the new first flashcopy map and will not be recopied.

FIG. **5** represents a first cyclic incremental flashcopy. The mirroring control previous future flashcopy bitmap has been applied to update the first flashcopy bitmap **90**, as discussed above. In the example, the "0" at bit positions **115**, **116**, **117** and **118** indicate that the data at grains **110**, **111**, **112** and **113** has been modified or updated and is to be mirrored. The mirroring

control then conducts the first cyclic incremental flashcopy of the source data storage for grains **110, 111, 112** and **113**, the beginning of the first cyclic incremental flashcopy comprising a consistency point.

Referring to FIG. **6**, the data of the source data storage **61** is being updated by an update write. The mirroring control determines whether data of the data storage **61** to be overwritten by the update write is present at the data storage **62**, in the example, by consulting the bit map **90**. If the previous data (which is to be overwritten) has been copied and is at the data storage **62**, the mirroring control allows the update write to be written to the data storage **61**, and indicates the update write in a future flashcopy map **91**. In the example, the data to be mirrored of grains **110, 111** and **112** of data storage **61** has been copied to grains **120, 121** and **122** of data storage **62**, as indicated by bits **115, 116** and **117** of bit map **90**, and thus the update write to grain **110** can be conducted.

In one embodiment, else, meaning that the previous data (which is to be overwritten) has not been copied to the source data storage **62**, the mirroring control immediately copies the present data of the source data storage **61** to be overwritten to data storage **62**, and then allows the update write to be written to the source data storage **61**, and indicates the update write in the future flashcopy map **91**. If the copying is immediate to allow an immediate update write, the action is called a "Copy on Write" or "COW". In the example, the data of grain **113** has not been copied to data storage **62**, as indicated by the "**0**" of bit **118** of bit map **90**. Thus, the mirroring control copies the data of grain **113** the data storage **61** to be overwritten to data storage **62**, changes bit **118** of bit map **90** to a "**1**" to indicate that the data has been copied, and allows the

update write of data **125** to be written to grain **113** of the data storage **61**, and indicates the update write in the future flashcopy map **91**. Alternatively, the update write to source data storage **61** is held until the present data is copied to data storage **62**, and the bit of bit map **90** for that grain has been set to "1".

Still referring to FIG. **6**, in a further embodiment, the mirroring control merges the first flashcopy map **90** with the future flashcopy map **91** to generate a new first flashcopy map **90**, and resets the future flashcopy map **91**, adding the indication of the grain whose data is to be synchronously copied as the data is written to that grain of source data storage **61**; the beginning of a new first cyclic incremental flashcopy comprising a consistency point, and the process is repeated as the data of the grain is copied to the first intermediate data storage **62** and the second intermediate data storage. The commit to the consistency point including the data to be synchronously mirrored comprises the "command complete" for mirroring.

In the examples of FIGS. **3**, **4**, **5** and **6**, data storage **61** and data storage **62** have been discussed. In the case of copying data from grains of source data storage **61** of FIG. **2A** to first intermediate data storage **62** with a first incremental flashcopy **70**, or of source data storage **61** of FIG. **2C** with a first cyclic incremental flashcopy **80**, the data is synchronously mirrored to the second intermediate data storage **63**, and the bit map **90** represents the state of both the first intermediate data storage **62** and the second intermediate data storage **63**. In the case of copying data from grains of the second intermediate data storage **63** of FIG. **2B** or of FIG. **2C** to target data storage **64** with a second incremental flashcopy **73** of FIG. **2B** or with a second cyclic incremental flashcopy **83** of FIG. **2C**, the bit map **90** represents the state of the target data storage

64. Similarly, the future bit map **91** of the mirroring controller **28** with respect to first data storage system **24** represents the state of source data storage **61** with respect to updates from a host system, and another future bit map **91** of the mirroring controller **48** with respect to second data storage system **44** of FIG. **1** represents the state of the synchronously mirrored first intermediate data storage **62** and the second intermediate data storage **63** with respect to updates from source data storage **61** of FIGS. **2A**, **2B** and **2C**.

FIG. **7** depicts an embodiment a computer processor implemented method in accordance with the present invention. Mirroring, whether initial or cyclic, begins at step **140.**

A first incremental flashcopy is conducted in step **142**, comprising a number of substeps. In substep **143**, the bit map **90** of FIGS. **3**, **4**, **5** or **6** is updated as discussed above. The bit map is updated to identify the grains that need to be mirrored from the source data storage **61** to the target data storage **64** of FIG. **2A** or of FIG. **2C**. The data to be mirrored becomes the consistency point **144** of the source data storage. In substep **145** of FIG. **7**, the bit map is scanned to determine the next grain to copy, for example, by the bit map indicating a "**0**" for that grain. The scan may be in any suitable order, or, in the case of a COW, may be only for the data required to be copied for the COW. In substep **147**, the grain determined to be copied is copied to the first intermediate data storage **62** and synchronously mirrored to the second intermediate data storage **63** of FIG. **2A** or of FIG. **2C**. In substep **148** of FIG. **7**, the bit for that grain is set to "**1**" to indicate that the grain has been copied.

Step **150** indicates a command to update or modify the data of a grain with an update write, as discussed above. In step **151**, a check is made of the bit map **90** of FIGS. **3**, **4**, **5** or **6** to

determine if the data of the source data storage **61** to be overwritten by the update write is present at the synchronously mirrored first intermediate data storage **62** and the second intermediate data storage **63**. If so, in step **155** of FIG. **7**, the mirroring control allows the update write to be written to the source data storage, and indicates the update write in the future flashcopy map **91** of FIGS. **3**, **4**, **5** or **6**; else, in one embodiment, in substep **145** of FIG. **7**, the mirroring control identifies the grain having the data to be overwritten as a grain to be immediately copied. In substep **147**, the present data of the grain of the source data storage to be overwritten is copied to the first intermediate data storage and synchronously mirrored to the second intermediate data storage, and, sets the bit for that grain to "1" to indicate that the grain has been copied in substep **148**. Then, the mirroring control allows the update write to be written to the source data storage in step **155**, and, in step **156**, indicates the update write in the future flashcopy map **91** of FIGS. **3**, **4**, **5** or **6**. Alternatively, if the present data of the grain has not been copied to the first intermeidate data storage and synchronously mirrored to the second intermediate data storage, the update write of step **150** is held in step **157** until completion of substeps **147** and **148** for the present data of the grain. The synchronous copying of step **147** may be conducted in a normal order, or alternatively may be conducted as a "COW" as discussed above. Step **158** of FIG. **7** represents a loop to repeat the process until all of the data of the grains of the consistency point of step **144** have been copied to the first intermediate data storage **62** and synchronously mirrored to the second intermediate data storage of FIGS. **3**, **4**, **5** or **6**.

When all of the data has been synchronously mirrored, the mirroring is signaled as complete in step **160** of FIG. **7**.

A second incremental flashcopy is conducted in step **162**. The beginning of the second cyclic incremental flashcopy comprising commit of the consistency point, and the commit is communicated to the controller **28** of the first data storage system **24** of FIGS. **3**, **4**, **5** or **6** in step **164** of FIG. **7**. Step **162** comprises a number of substeps, which are substantially similar to that of step **142**, discussed above. In substep **163**, the bit map **90** of FIGS. **3**, **4**, **5** or **6** is updated in accordance with the data to be transferred from the second intermediate data storage **63** to the target data storage **64** of FIGS. **2B** or **2C**, as discussed above. In one example, the transfer of data represented by the previous consistency point has been transferred to the target data storage such that the transfer is complete. If so, the new data to be transferred becomes the entry to the bit map. Alternatively, if the new consistency point is provided before the previous data transfer to the target data storage **64** has been completed, the content of the previous bit map **90** at the time of the new consistency point is merged with the bits representing the new consistency point. In substep **165** of FIG. **7**, the bit map is scanned to determine the next grain to copy, for example, by the bit map indicating a "0" for that grain. The scan may be in any suitable order, and, in one example, may comprise the oldest uncopied data in a first in, first out scheme. In substep **167**, the grain determined to be copied is copied from the second intermediate data storage **63** of FIG. **2B** or of FIG. **2C** to the target data storage **64**, completing the mirroring of that data grain. In substep **168** of FIG. **7**, the bit for that grain is set to "1" to indicate that the grain has been copied.

If data for a grain for a future consistency point is supplied to second intermediate data storage **63** of FIG. **2C**, after the data of the original consistency point for that grain has been copied to the target data storage **64**, such that the mirroring of that grain is complete, step **176** of

FIG. **7** comprises an update write for a future flashcopy map **91** of FIGS. **3, 4, 5** or **6** for the second incremental flashcopy of FIG. **2C**.

Step **178** of FIG. **7** represents a loop to repeat the process until all of the data of the grains of the consistency point of step **144** have been copied to the target data storage **64** of FIGS. **3, 4, 5** or **6**. As discussed above, step **162** of FIG. **7** does not require completion to begin a new consistency point.

Referring to FIG. **8**, a read operation for reading the mirrored data from the second data storage system **44** of FIGS. **1** and **2C**, for example, for disaster recovery, is begun at step **190**. In step **191**, the bit position for the data grain for incremental flashcopy **83** is checked to determine whether the data of the grain representing the latest committed consistency point has been copied to the target data storage. In step **193**, the bit of the bit map is read. For example, referring to FIG. **6**, if the data of grain **121** is to be read, bit position **116** of bit map **90** indicates that the data of grain **121** of target data storage **64** is the most recent. Thus, in step **195** of FIG. **8**, the data is read from grain **121** of FIG. **6**. If, instead, the data of grain **123** is to be read, bit position **118** of bit map **90** indicates that the most recent data has not been copied and is at grain **113** of second intermediate data storage **63**, and is to be read from the second intermediate data storage, since it was committed. Thus, in step **197** of FIG. **8**, the data is read from grain **113** of FIG. **6** of second intermediate data storage **63**.

The illustrated components of the information handling system(s) of FIG. **1** and of FIGS. **2A, 2B** and **2C**, and the arrangement of the bit maps and data grains of FIGS. **3, 4, 5** or **6** may be varied, combined, or combined functions may be separated, as is known to those of skill in the

art. The illustrated steps of FIGS. **7** and **8** may be altered in sequence, omitted, or other steps added, as is known to those of skill in the art.

While the preferred embodiments of the present invention have been illustrated in detail, it should be apparent that modifications and adaptations to those embodiments may occur to one skilled in the art without departing from the scope of the present invention as set forth in the following claims.